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(54) A transponder system

(57) Transponder signal collision avoidance system includes a reader and wireless HDX or FDX type transponders (A, B) are disclosed, interrogated by the reader (R) by alternately powering and then reading through cycles corresponding to a number of possible transponders in the interrogation field. The cycles, which include reader power pulses, signify addresses of respective possible transponders, whether in or out of the field. The transponders for this purpose count reader power pulses by end-of-burst detection, increasing a stored count value with each reader power pulse. The transponder responds to the reader by transmission if and only if a stored count value in a read cycle matches a respective transponder address, preventing the transponders from transmitting telegrams interfering with each other. As a method of reader-transponder operation, the collision avoidance scheme thus cycles the reader interrogating through cycles having power pulses according to possible transponders in the field, not only calling the addresses of each of respective possible transponders but also shortening or lengthening read and power steps dependent upon responses received from the transponders.

TRANSPONDER FLOW CHART

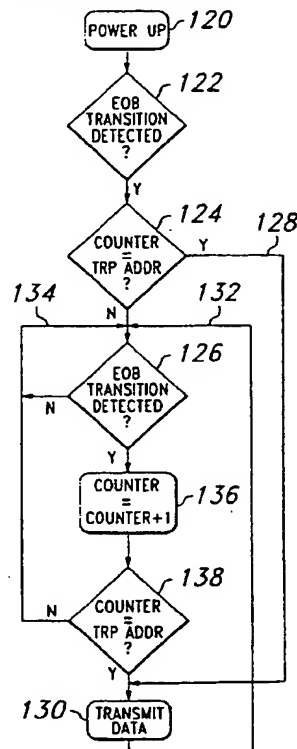


Fig. 4B

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Description

FIELD OF THE INVENTION

5 [0001] The invention relates to a transponder system and method of operation thereof and, more particularly, to a system for preventing message signal collision of multiple wireless transponders in a wireless interrogation field from interfering with identification of the respective transponder messages, i.e., their so-called telegrams. Accordingly, the proposed transponder collision avoidance system avoids telegram collision with attendant advantages.

10 [0002] Self-contained, miniaturized transponders, i.e., radio transponders, are known that employ an interrogator-transponder arrangement which may be independently powered, e.g., having an EEPROM data storage device and a transponder charge capacitor used as an energy accumulator charged by the energy of radio frequency interrogation to thereby power the transponder. Such a transponder arrangement is disclosed in Schuermann et al. U.S. Patent 5,053,774, herein incorporated by reference.

15 [0003] Such transponders each transmit their radio telegrams upon being interrogated by a so-called reader. The wireless transmission of a transponder, e.g., as may convey serial number or address and any of a variety of parameters such as temperature or pressure, or other data, may herein be termed a telegram.

20 [0004] In a system employing multiple such transponders which may be miniaturized, independent, low cost and of relative simplicity, the transponders are not able to communicate with each other to avoid interference so that collision of their respective so-called telegrams may result, such that it may be impossible for the reader to distinguish their respective telegrams. Such a problem may arise when, after the interrogation signal of the reader, the transponders all initiate their telegram at the same time. Thus, it is desired to allow the transponders in the interrogation field to transmit their respective telegrams successively without mutual interference and without excessive loss of time.

25 [0005] Multiple possible solutions may exist to overcome the collision problem. One such proposed solution uses a comparison between a selective address and the content of a transponder memory to avoid response of an unaddressed transponder, in which transponder the charge capacitor is discharged and therefore oscillation is stopped before the transponder can transmit. A disadvantage in the latter approach is that each transponder must be addressed separately, which requires considerable time and so degrades throughput; and moreover the respective transponder addresses must be completely known so that only a preselected transponder will be caused to respond.

30 SUMMARY OF THE INVENTION

[0006] It is in view of the above problems that the present invention is proposed. The present invention contemplates initiating in the multiple transponders a predetermined transmission delay interval for the respective transponder so that the data telegrams of the multiple transponders provide transmission of telegrams successively without mutual interference and without excessive loss of time.

35 [0007] Among the several advantages and features of the invention may be noted the provision of an improved transponder anti-collision system which is suitable for either half-duplex (HDX) transponder systems or full-duplex (FDX) transponder systems using any type of modulation.

40 [0008] As a further advantage, the reader of such a system can be compatible with the existing installations, so that a reader configured according to the present system proposal can read existing transponders as well as transponders configured according to the present system proposal for avoiding interrogation telegram collision.

[0009] A still further advantage is that transponders of the system are readily configured in accordance with the proposed system, requiring only simple circuit additions to existing transponder circuitry to achieve the modes of operation herein proposed.

45 [0010] Briefly, an inventive transponder signal collision avoidance system comprises a reader and a plurality of wireless transponders for being interrogated by the reader within a wireless interrogation field, the reader being adapted for interrogating through a number of cycles corresponding to a number of possible transponders in the field, the cycles include power pulses by which the transponders receive power for responding, and which power pulses signify addresses of each of respective possible transponders. The transponders for this purpose count reader power pulses, increasing a predetermined value, i.e., a stored bit pattern, with each reader power pulse. The transponders are each adapted to respond to the reader by transmission only in response to a received transmission value corresponding to the address of the respective transponder, whereby to prevent the transponders from transmitting respective messages without interfering with each other.

50 [0011] Thus, the system carries out a method of wireless reader-transponder operation for transponder signal collision avoidance comprising providing a reader and a plurality of wireless transponders for being interrogated by the reader within a wireless interrogation field, cycling the reader interrogating by transmitting power pulses through a plurality of cycles of interrogation of possible transponders in the field, the cycles calling the addresses of each of respective possible transponders, causing the transponders each to respond to the reader by transmission only in response

to a received address of the respective transponder, whereby to prevent the transponders from transmitting respective messages without interfering with each other.

[0012] Other advantages, objects and features will be apparent or are pointed out herein.

5 BRIEF DESCRIPTION OF DRAWINGS

[0013] The present invention will now be further described, by way of example, with reference to the accompanying drawings in which:

10 FIG. 1 is a block diagram operation of a system in accordance with the invention;

FIG. 2 is a block diagram of the configuration of an HDX transponder as modified in accordance with the invention to provide the proposed collision-avoidance mode of operation;

15 FIG. 3 is a block diagram of the configuration of an FDX transponder as modified in accordance with the invention to provide the proposed collision-avoidance mode of operation;

FIGS. 4A and 4B are interrelated flow charts together showing steps in the operation of a reader and typical transponder of the system, wherein:

20 FIG. 4A is termed the reader flow chart and shows steps in the operation of a reader of the system operating according to system requirements; and

25 FIG. 4B is termed the transponder flow chart and shows steps in the operation of a typical transponder configured according to FIG. 2;

FIG. 5 is an exemplary reader timing diagram;

30 FIG. 6 is a timing diagram with conditions indicative of a number of transponders to be detected, only one transponder being present within the interrogation field; and

FIG. 7 is a timing diagram with conditions indicative of the same number of transponders to be detected, all of a maximum number of transponders being present, as the system is adjusted according to a desired embodiment.

35 [0014] Corresponding reference characters identify corresponding elements throughout the several views of the drawings.

DESCRIPTION OF INVENTIVE EMBODIMENTS

40 [0015] Referring to the drawings, FIG. 1 shows a block diagram of a wireless interrogation system of the half-duplex (HDX) type generally disclosed in above-cited Schuermann et al. U.S. Patent 5,053,774 including an interrogator-reader (reader) 2 and its antenna 4 by which one miniaturized transponder A,B as typical of others in field f is interrogated by reader 2 and FSK-modulated data may be read from the transponder by the reader according to known technique, with the transponder powered by RF from antenna 4.

45 [0016] Referring to FIG. 2, an HDX transponder A includes a resonant circuit comprising an inductor L_R and a capacitor C_R for both receiving an interrogation signal and for transmitting a response. Inductor L_R , being of very compact dimensions, serves as an antenna of the transponder for receiving and transmitting.

[0017] Transponder A is representative of each of several transponders $A_1, A_2 \dots A_n$ in field f to be interrogated by an interrogator, i.e., a reader (not shown) in accordance with the teachings of Patent 5,053,774. It will be understood that each of the transponders in a wireless interrogation field carries a unique identification, namely a unique bit pattern constituting a preset value, as representing the "address" of the respective transponder. By such addresses, the transponders and reader are prevented from interfering with identification of the respective transponder messages, (i.e., their so-called telegrams,) by transmitting only if the address is received and thereby preventing transponder telegram collision.

55 [0018] When interrogated, each transponder, being provided with a diode D_1 clamping one side of the resonant circuit to circuit ground, stores charge in a charge capacitor C_C from received radio frequency energy for so long as the interrogation signal is received, e.g., for a period of milliseconds. As will be seen from the following description the resultant charge in capacitor C_C provides the sole source of power for operation of the transponder, and represents a stored volt-

is increased by a count of 1 after the high-low (H-L) transition (except the first transition). If after the first H-L transition one of the transponders has the same bit pattern (meaning that the value in its counter 12 matches the increased comparator value (a condition referred to herein as a match), an EOB signal will be generated in response to the detected end-of-burst to trigger the transponder circuit in accordance with the previous description. The circuit thus triggers the oscillation of resonant circuit comprising inductor L_R and capacitor C_R , by activation of pluck circuit 26, so that transponder starts the transmission process, as powered by the energy accumulated in C_C .

[0034] The other transponders wherein the value does not match stop their oscillation as signalled by OSCOFF to effectively short circuit the resonant circuit of each such other transponder wherein the respective pluck circuit is accordingly not activated. Such other transponders thus remain passive, but the supply voltage V_{CC} remains stored in charge capacitor C_C of each transponder.

[0035] If, however, there is no transponder with the same value as sent by the reader, and thus no transponder comparator detects a match, all transponders remain in a stand-by mode as no conditions exist in any transponder to trigger oscillation by the transponder.

[0036] During a third phase (3,7) shown in Fig. 5 all transponders are recharged. The H-L transitions 3 to 4, 5 to 6, 7 to 8 each generate a new clock pulse to increase the respective counter's value.

[0037] Referring to FIG. 4A, showing steps/sequences of operation as a reader flow diagram, there is first shown a start 100, and from operation proceeds to power step 102, and thereafter a short transponder read step 104 of, e.g., 3ms duration, during which it will be understood that by reading, the reader is in a receiving mode in which it listens for any transmission from a transponder. A query 106 follows in which the reader determines if any transponder is detected, and thus may be referred to as checking to see if a transponder is detected. If a transponder response is not detected (N), a short power step 108 of, e.g., 5ms ensues, followed by transponder read step 104 again. If a transponder response is detected (Y), a longer read step 110 of, e.g., 20ms provides for transponder reading of data from the transmitting transponder. Then a still longer power step is provided for, e.g., 20ms as shown at step 112. The cycle count is then queried at 114. If the cycle count is not (N) greater than a value of 8, e.g., as being the predetermined number of transponders to be read, the process loops back as indicated at 116 to step 104 for another cycle. If the cycle count is (Y) greater than a value of 8, the sequence of steps is terminated as shown at end 118. Thus, it will be apparent that if no transponder is detected, the reader will be successively cycled only through steps 102, 104 and 106 in sequence, namely powering, reading and checking, or may be carried out selectively as steps 100, 102, 104 and 106 on an predetermined basis.

[0038] FIG. 4B shows corresponding steps at a transponder. A power-up period is shown as step 120 during which the charge capacitor C_C charges up to provide voltage V_{CC} . If then at step 122 an EOB signal is detected, operation continues to the determination as represented by step 124 of whether the counter has a count value equal to that corresponding to the transponder address. If not (N), operation proceeds to determining again at decision block 126 whether there is an EOB transition detected. But if yes (Y), the counter has a count value equal to that corresponding to the transponder address, operation proceeds as indicated at 128 to a sequence 130 of transmitting the transponder data to the reader, whereupon the flow then proceeds as indicated at 132 back to query 126 to determine whether there is an EOB transition detected. If not (N), operation is redirected and another query 126 is made. But if yes (Y), operation proceeds from query 126 to step 136 in which counter 12 is incremented by a value of 1 (COUNTER=COUNTER + 1). The sequence of operation then queries at 138 whether the counter value equals that corresponding to the transponder address. If not (N), operation is redirected by path 134 to checking again at decision block 126 whether an EOB is detected. If yes (Y), operation proceeds once more to transmit data sequence 130.

[0039] Thus, comparing FIGS. 4A and 4B with FIG. 5, it will be understood with reference to FIG. 5 that at phase 1 all transponders are charged up and the reader is ready to receive the transponder telegrams at phase 2. If after a short read period of, e.g., 2-3ms no signal is detected the reader transmitter starts to power again for a short power step for a period, e.g., 5-10ms to recharge all transponders in the interrogation field (phase 3). In phase 4 the reader has detected a transponder signal within a 2-3ms brief read step or segment and thus extends the receive phase to 20ms. After such an extended receive period or sequence a longer charge up time is necessary by providing an extended power period (e.g., 10-20ms), as shown in phase 5. The reader continues to power and read, through power and read steps, until the predetermined number of transponders (with corresponding interrogation read cycles) has been reached. Such may for example be 8 or 16 read cycles.

[0040] Because system speed is lowered by a greater number of transponders to be interrogated (speed being dependent on the number of the transponders to be detected), the present solution to transponder collision avoidance will be found suitable for specific applications and not all applications. It is to be further appreciated that resolution is dependent on the number of used bits.

[0041] It is noted that in the special case of two transponders in the interrogation field having the same bit pattern, the reader can recognize this occurrence because there will be a field generated by the transponders but not a valid read.

[0042] The examples appearing on following pages are illustrative. They indicate exemplary timing sequences considered to be appropriate for conditions of different possible numbers of transponders in the interrogation field. Those

skilled in the art may vary timing of steps and sequences to achieve the results of the invention.

Example 1

[0043] Referring to FIG. 6, the timing diagram illustrates timing conditions typical where there are, in this example, 8 transponders to be detected but only one transponder is present. The following table illustrates typical sequences and their lengths:

(Table 1)

Read Short (RS)=3ms
Read Long (RL)=20ms
Power Short (PS)=5ms
Power Long (PL)=20ms
POWER=50ms

[0044] As accordingly evident from FIG. 6, the sequence of operation proceeds through a power phase of 50ms and then through a total of 8 subsequent phases, and where in phase 6 RL includes reading of the sixth of 8 transponders, and is followed by PL. The total period T is thus defined by

$$T = \text{POWER} + \text{RS} \cdot 3 + \text{PS} \cdot 5 + \text{RL} + \text{PL} \quad (\text{Equation 1a})$$

so that

$$T = 50\text{ms} + 7 \cdot 3\text{ms} + 6 \cdot 5\text{ms} + 20\text{ms} + 20\text{ms} = 141\text{ms} \quad (\text{Equation 1b})$$

Example 2

[0045] Referring to FIG. 7, the timing diagram illustrates timing conditions typical where there are, in this example, 8 transponders to be detected and all 8 transponders are present.

[0046] The total period T in this case similarly

$$T = \text{POWER} + 8 \cdot \text{RL} + 7 \cdot \text{PL} \quad (\text{Equation 2a})$$

whereby

$$T = 50\text{ms} + 8 \cdot 20\text{ms} + 7 \cdot 20\text{ms} = 350\text{ms} \quad (\text{Equation 2b})$$

Example 3

[0047] Similarly, in the event of 16 transponders to be detected and all 16 transponders being present, the total period T is

$$T = \text{POWER} + 16 \cdot \text{RL} + 15 \cdot \text{PL} \quad (\text{Equation 3a})$$

such that

$$T = 50\text{ms} + 16 \cdot 20\text{ms} + 15 \cdot 20\text{ms} = 670\text{ms} \quad (\text{Equation 3b})$$

and the sequence of phases will be evident from the pattern generally given by FIG. 7.

[0048] The inventive new system is thus seen to achieve substantial advantages in a HDX and FDX type system for preventing message signal collision of multiple wireless transponders in a wireless interrogation field from interfering with identification of the respective transponder messages, (i.e., their so-called telegrams). The transponder collision avoidance system avoids telegram collision with attendant advantages. It involves convenient modification of an existing HDX or FDX-type reader without departing from the existing reader principles of operation except as will be within the

province of the skilled artisan to sequence the additional steps, but it still is compatible with existing installations and so achieves desirable backward compatibility with legacy suitability. This also means the modified reader can read existing transponders. As a further advantage, existing transponder designs are readily modified as evident from the foregoing whether for HDX transponder (FIG. 2) or FDX transponder (FIG. 3) configurations, and transponder data can be transmitted reliably to the reader as by using system typical modulation.

[0049] In view of the foregoing description of the present invention and various embodiments and methods it will be seen that the several objects of the invention are achieved and other advantages are attained.

[0050] The embodiments were chosen and described in order to best explain the principles of the invention and its practical application to thereby enable others skilled in the art to best utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated.

[0051] As various modifications could be made in the constructions and methods herein described and illustrated without departing from the scope of the invention, it is intended that all matter contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative rather than limiting.

Claims

1. A transponder system for signal collision avoidance comprising a reader and a plurality of wireless transponders for being interrogated by the reader within a wireless interrogation field, the reader being adapted for interrogating by transmitting power pulses through a number of cycles corresponding to a number of possible transponders in the field, the cycles corresponding to the addresses of each of respective possible transponders, the transponders each being adapted to respond to the reader by transmission only in response to a transmission value determined by the transponders as corresponding to the address of the respective transponder, whereby to prevent the transponders from transmitting respective messages without interfering with each other.
2. A transponder system as set forth in Claim 1, wherein each transponder comprises a counter for counting a number of power transmissions by the reader and storing a count value, and circuitry for determining if the stored count identifies the respective transmitter, and circuitry for preventing transmission by the respective transponder if the stored count value does not identify the respective transponder.
3. A transponder system as set forth in Claim 2, wherein the circuitry for determining if the stored bit pattern identifies the respective transmitter comprises a memory for storing a preset address value representing the address of the transponder and a comparator for comparing the stored count value with the preset address value.
4. A transponder system as set forth in Claim 3 wherein the circuitry for preventing transmission by the respective transponder if the stored bit pattern does not identify the respective transponder comprises logic circuitry responsive to the comparator for terminating transmission by the respective transponder.
5. A transponder system as set forth in Claim 3 or Claim 4 wherein each transponder comprises a charge capacitor in which received frequency energy is stored when an interrogation signal is received from the reader, the resultant charge in the charge capacitor powering the transponder for operation, the logic circuitry responsive to the comparator for terminating transmission by the respective transponder by preventing oscillation powered by the charge capacitor.
6. A transponder system as set forth in Claim 4 or Claim 5, wherein the logic circuitry comprises a monoflop controlling the transmission status of the transponder in response to the comparator.
7. A transponder system as set forth in any of Claims 4 to 6 wherein the transponder includes an end-of-burst (EOB) detector for determining the end of a received transmission burst and providing an EOB signal for incrementing the count value stored by the counter upon EOB detections, the comparator providing a comparison match output if the count value matches the preset address value, and the logic circuitry comprises first and second logic gates for controlling the toggling of the monoflop as a function of a comparison match output and the EOB signal.
8. A transponder system as set forth in any preceding claim, wherein the system provides half-duplex operation.
9. A transponder system as set forth in any of Claims 1 to 7 wherein the system provides full-duplex operation.
10. A transponder system as set forth in any preceding claim, wherein the respective transponders provide their transmissions successively.

11. A method of wireless reader-transponder operation for interrogating possible transponders in a wireless field by the use of a reader and controlling respective ones of the transponder such as to avoid signal collision of transmissions from the respective transponders when interrogated by the reader comprising operating the reader by interrogating by transmitting power pulses through a number of cycles corresponding to a number of possible transponders in the field, the cycles corresponding to the addresses of each of respective possible transponders, and selectively permitting the respective transponders to respond to the reader by transmission only in response to a count of power pulses corresponding to the address of the respective transponder, whereby transponders in the field transmit respective messages sequentially without interfering with each other.
12. The method as set forth in Claim 11 further comprising; storing in each transponder an address value uniquely characteristic of the respective transponder, receiving and storing as a count value a bit pattern representing a number of received power pulses while transmissions are received by the transponder from the reader and comparing the count value during interrogation with the address value for determining if the stored bit pattern identifies the respective transmitter, and preventing transmission by the respective transponder if the stored bit pattern does not identify the respective transponder.
13. The method as set forth in Claim 12, further comprising; storing in a charge capacitor of each transponder received radio frequency energy provided during said reader power pulses for powering the respective transponder when an interrogation signal is received from the reader.
14. The method as set forth in Claim 12 or Claim 13 further comprising; preventing preventing transmission by the respective transponder if the stored bit pattern during interrogation does not identify the respective transponder.
15. The method as set forth in any of Claims 12 to 14, wherein in each transponder the step of comparing the stored count value during interrogation with the address value for determining if the stored count value identifies the respective transmitter provides a match signal if the stored count value identifies the respective transmitter, and further comprising detecting in each transponder an end-of-burst (EOB) of transmission by the reader and signalling same by an EOB signal, initiating a transmission by the transponder upon the presence of both EOB and match signals, and preventing transmission oscillation by the respective transponder if there is an EOB signal without a corresponding match signal.
16. The method as set forth in any of Claim 13 to 15, wherein the step of operating the reader comprises providing cycles of operation each having a first power step sending a transponder power-up signal, and a read step for reading responses from any of the transponders, determining if any transponder response is detected, and then again re-initiating as a new cycle another power step if no response is detected, and subsequently reading responses from any transponder, but if a transponder response is detected extending the cycle by providing a read step longer than the first read step for transponder reading, again providing a further power step, counting cycle count to determine a cycle count, repeating the cycle until as many cycles are completed as correspond to the number of possible transponders.
17. The method as set forth in claim 16 further comprising; providing an elongated read period for reading of data during transmission of a transponder during an interrogation cycle in which the respective transmitter provides a match signal if the stored count value identifies the respective transmitter and during which read period data is provided from the respective transponder to the reader.
18. The method as set forth in Claim 16 or 17 further comprising; providing an elongated power period by the reader following the elongated read period.
19. The method of wireless reader-transponder operation for transponder signal collision avoidance comprising; providing a reader and a plurality of wireless transponders for being interrogated by the reader within a wireless interrogation field, cycling the reader interrogating by transmitting power pulses through a plurality of cycles of interrogation of possible transponders in the field, the cycles calling the addresses of each of respective possible transponders, causing the transponders each to respond to the reader by transmission only in response to a received address of the respective transponder, whereby to prevent the transponders from transmitting respective messages without interfering with each other.
20. The method as set forth in Claim 19, wherein the transponders operate in either HDX or FDX mode.

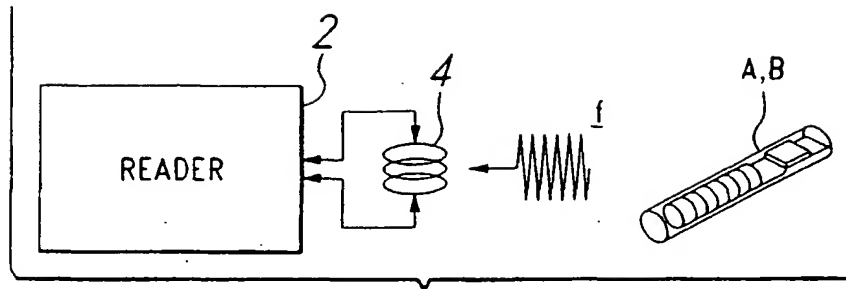


Fig. 1

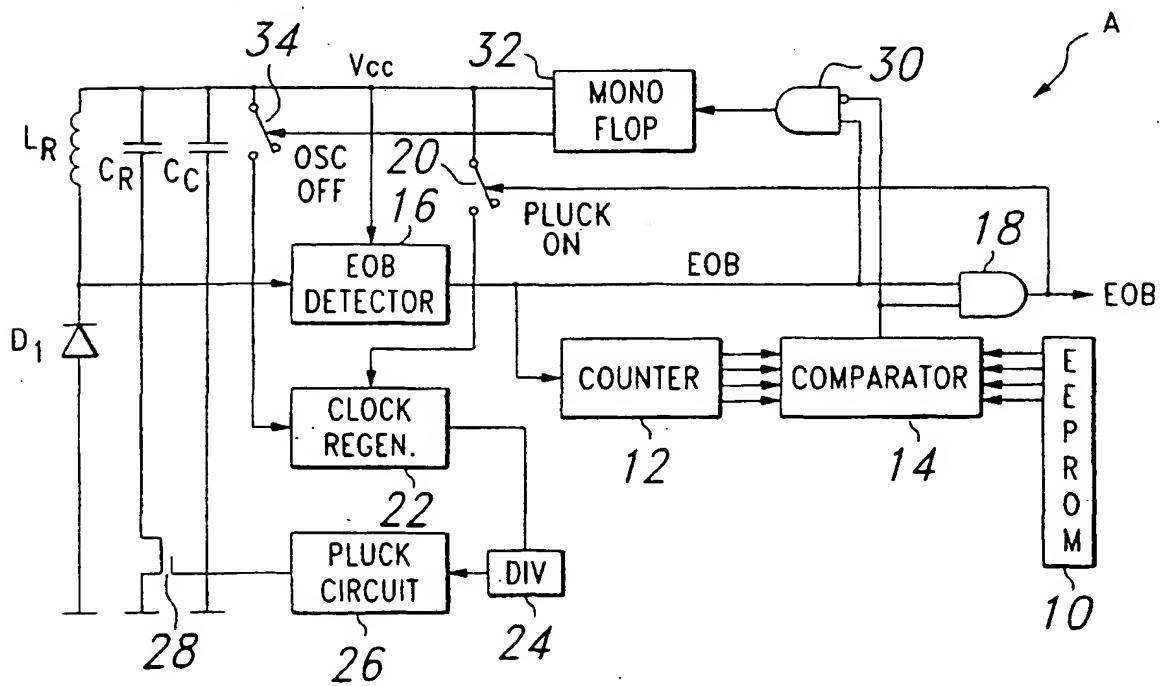


Fig. 2

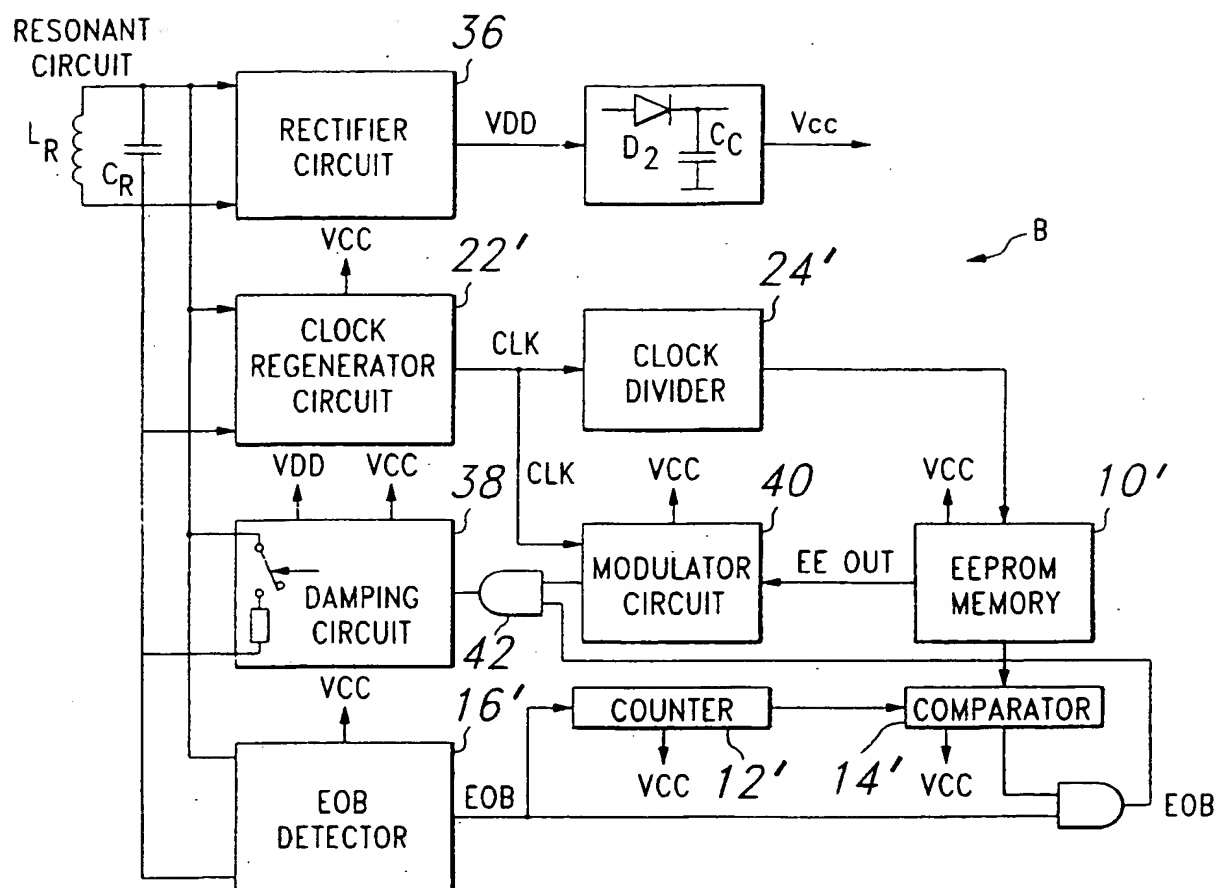


Fig. 3

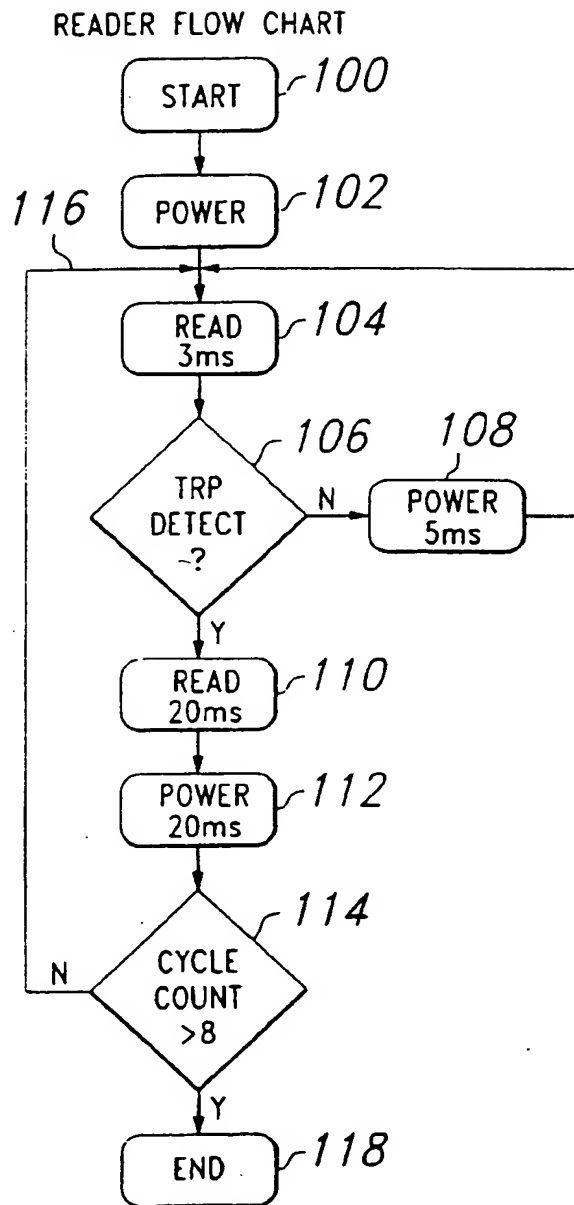


Fig. 4A

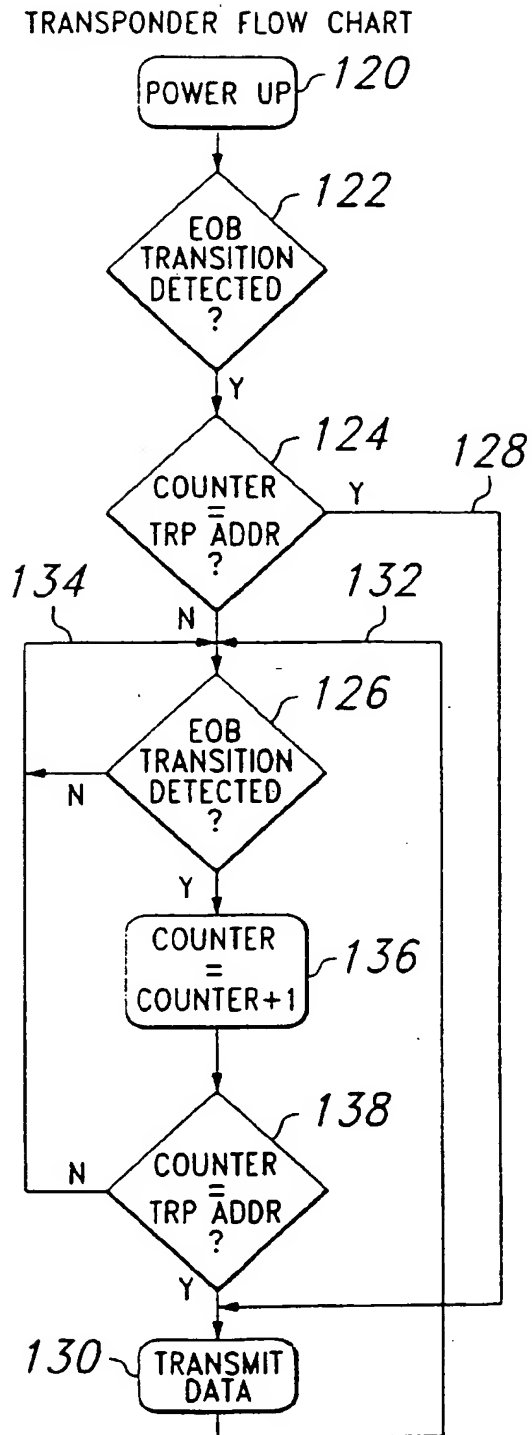


Fig. 4B

Fig. 5

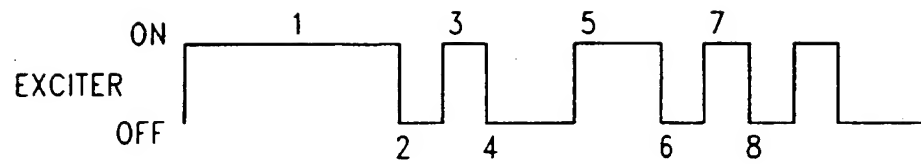


Fig. 6

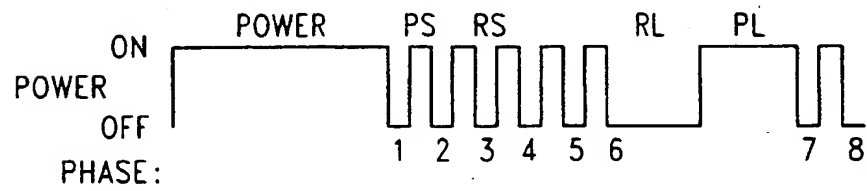
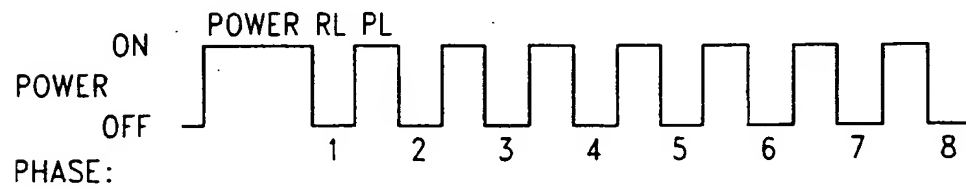


Fig. 7





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 12 0860

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	EP 0 768 540 A (TEXAS INSTRUMENTS DEUTSCHLAND) 16 April 1997 * column 3, line 30 - line 44 * * column 4, line 49 - column 6, line 21 *	1,8,9, 11,19,20	G06K7/00
A	GB 2 259 227 A (MARCONI GEC LTD) 3 March 1993 * page 1, paragraph 3 - page 3, paragraph 3 * * figures *	1,11,19	
A	US 5 453 747 A (D HONT LOEK ET AL) 26 September 1995 * column 1, line 53 - column 2, line 6 *	1,11,19	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			G06K
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 26 May 1998	Examiner Goossens, A
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ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 97 12 0860

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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26-05-1998

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82